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Fort Monmouth, New Jersey

Remedial Investigation Report Addendum

M-4 Landfill Site

Fort Monmouth, New Jersey

January 14, 2011

REMEDIAL INVESTIGATION REPORT ADDENDUM FOR THE M-4 LANDFILL SITE FORT MONMOUTH, NEW JERSEY

PREPARED FOR:

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EXECUTIVE SUMMARY

Tetra Tech Inc. (Tetra Tech) has been contracted by the U.S. Army Installation Fort Monmouth Directorate of Public Works (DPW) to prepare a Remedial Investigation Report Addendum (RIRA) for the M-4 Landfill site located in the Fort Monmouth Main Post area in Fort Monmouth, New Jersey. This report addresses the remedial investigation activities conducted at the site between April 2001 and September 2010.

The M-4 Landfill site is bordered by North Drive to the north, Wilson Avenue to the east, the Avenue of Memories to the south, and Mill Creek intersects M-4 Landfill in the Main Post area of Fort Monmouth. The M-4 Landfill site covers approximately 61,800 square feet (1.4 acres). Aerial photographs dated 1940 depict the M-4 Landfill site as a swamp. The M-4 Landfill site was historically used as a landfill in 1955 and 1956 for the disposal of demolition debris.

Remedial groundwater investigation activities were conducted between April 2001 and July 2010. Remedial surface water investigation activities were performed between May 2001 and September 2010. The results of these investigations are presented in this report.

A total of five groundwater monitoring wells (M4-MW06, M4-MW07, M4-MW08, M4-MW09 and M4-MW10) comprise the quarterly groundwater monitoring program conducted by the DPW at the M-4 Landfill site. A total of 190 samples were collected during of the groundwater sampling program. No volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides, or polychlorinated biphenyls (PCB) were detected at concentrations exceeding the New Jersey Department of Environmental Protection (NJDEP) Ground Water Quality Criteria (GWQC) in the groundwater samples collected from the M-4 Landfill site. A total of seven metals were detected at concentrations exceeding the NJDEP groundwater criteria. However, based on the potential contaminant of concerns (COC) evaluation process, these metals were eliminated as potential COCs at the M-4 Landfill site.

In order to determine whether groundwater contamination at the M-4 Landfill site has impacted nearby surface water, DPW conducted quarterly surface water sampling at the M-4 Landfill site between May 2001 and September 2010. From May 2001 to September 2010, at total of 90 surface water samples were collected during 38 quarterly sampling events and were analyzed for VOCs and target analyte list (TAL) metals. Two VOCs and four metals were detected at concentrations exceeding the NJDEP Surface Water Quality Standards (SWQS). However, these compounds were eliminated as potential COCs with respect to groundwater and are not considered to impact nearby surface water at the M-4 Landfill site.

It is the DPW's contention that VOC and metal concentrations detected in surface water samples above the NJDEP surface water criteria are from a source upgradient of the M-4 Landfill site and beyond the boundary of Fort Monmouth. Therefore, based on DPW's assessment regarding surface water, and because no COCs exist in groundwater, No Further Action (NFA) is recommended concerning the surface water and groundwater at the M-4 Landfill site.

1.0 INTRODUCTION

Tetra Tech Inc. (Tetra Tech) has been contracted by the U.S. Army Installation Directorate of Public Works (DPW) to prepare a Remedial Investigation Report Addendum (RIRA) for the M-4 Landfill site located in the Fort Monmouth Main Post area in Fort Monmouth, New Jersey. This report addresses the remedial investigation activities conducted at the site between April 2001 and September 2010. This section describes the objectives and organization of this RIRA.

1.1. OBJECTIVE

The objective of this RIRA is to determine aquifer, chemical, and physical characteristics and to determine whether further remedial investigation or remedial action is required within the groundwater at the M-4 Landfill site. The remedial investigation was conducted in accordance with New Jersey Department of Environmental Protection (NJDEP) New Jersey Administrative Code (N.J.A.C) 7:26E - Technical Requirements for Site Remediation (NJDEP 1999).

The remedial investigation and subsequent preparation of the RIRA included:

- Characterization of groundwater quality through quarterly groundwater sampling events conducted between April 2001 and July 2010
- Characterization of surface water quality through quarterly surface water sampling events conducted between May 2001 and September 2010
- Comparison of groundwater and surface water results with NJDEP Ground Water Quality Criteria (GWQC) and Surface Water Quality Standards (SWQS).

1.2. REPORT ORGANIZATION

This report is organized to minimize repetition. Section 2.0 provides background information and a general description of the M-4 Landfill site located at the Main Post of Fort Monmouth. Section 3.0 describes and summarizes the remedial investigation (RI) field activities conducted at the M-4 Landfill site, including the groundwater and surface water sampling programs. Section 4.0 presents the physical characterization of the M-4 Landfill site including the lithology and groundwater conditions at the M-4 Landfill site. Section 5.0 presents site chemical characterization information, which includes groundwater and surface water sampling results and the determination of potential contaminants of concern (COC). Conclusions and recommendations for groundwater and surface water at the M-4 Landfill site are included in Section 6.0. References cited in this RIRA are listed after the text.

2.0 SITE BACKGROUND AND ENVIRONMENTAL SETTING

This section summarizes background information and describes the environmental setting of the area surrounding Fort Monmouth and the M-4 Landfill site. Specifically, this section describes the site and its location, summarizes site background information, presents current site conditions, and portrays the environmental setting of the M-4 Landfill site at the Fort Monmouth installation.

2.1. SITE LOCATION AND DESCRIPTION

Fort Monmouth is located in the central-eastern portion of New Jersey in Monmouth County, approximately 45 miles south of New York City and 70 miles northeast of Philadelphia (Figure 2-1). In addition to the Main Post, the installation includes two sub-posts, the Charles Wood area and the Evans area. The Main Post encompasses approximately 630 acres and bordered to the north by Parkers Creek, to the northeast by New Jersey Transit Railroad, to the east by State Highway 35, to the south/southeast by Oceanport Creek, and to the south by residential areas. The post was established in 1918 during World War I as an Army Signal Corps training center. The Main Post currently provides administrative, training, and housing support functions, as well as providing many of the community facilities for Fort Monmouth. The primary mission of Fort Monmouth is to provide command, administrative, and logistical support for U.S. Army Headquarters' Communications and Electronics Command (CECOM). CECOM is a major subordinate command of the U.S. Army Materiel Command (AMC) and is the host tenant at Fort Monmouth.

The M-4 Landfill site is bordered by North Drive to the north, Wilson Avenue to the east, the Avenue of Memories to the south, and Mill Creek intersects M-4 Landfill in the Main Post area of Fort Monmouth (Figure 2-2). The M-4 Landfill site covers approximately 61,800 square feet (1.4 acres). Aerial photographs dated 1940 depict the M-4 Landfill site as a swamp. The M-4 Landfill site was historically used as a landfill in 1955 and 1956 for the disposal of demolition debris. The 360-foot portion of the banks of Mill Creek flowing along the western perimeter of the M-4 Landfill site has been reinforced with concrete plates and covered with grass and shrubs.

2.2. PREVIOUS REMEDIAL INVESTIGATIONS

The U.S. Army Corps of Engineers (USACE), Baltimore District, contracted Roy F. Weston (Weston) to perform a field investigation of two areas at Fort Monmouth: the Main Post and the Charles Wood areas. Suspected hazardous waste sites were initially identified at Fort Monmouth in a report prepared by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) (USATHAMA 1980). The USATHAMA report identified 37 sites with known or suspected waste materials on the Main Post and the two sub-posts (Charles Wood and Evans areas). Weston conducted a background investigation of the 37 sites and eight additional sites that were identified by Fort Monmouth and NJDEP.

Weston's findings were described in the Investigation of Suspected Hazardous Waste Sites at Fort Monmouth, New Jersey report (Weston 1993). In this background report, additional investigations (including sampling and other field work) were recommended at 22 of the sites on

the Main Post and Charles Wood areas, including the M-4 Landfill site. NJDEP approved the recommendations on April 20, 1995. Additional investigations were also recommended at the Evans area, and such investigations are being completed under the Base Realignment and Closure (BRAC) program.

In the Site Investigation, Fort Monmouth, New Jersey, Main Post and Charles Wood Areas, Site Investigation Report (SIR) (Weston 1995), Weston presented the results of field investigation activities performed at 13 sites at the Main Post Area and eight sites at the Charles Wood Area. The results of the investigation of the M-4 Landfill site are included in the Weston SIR. Initial field investigation activities including surface water sampling, monitoring well installation, and groundwater sampling were performed between November 1994 and March 1995. The Weston SI report was used as the basis for the supplemental remedial investigations described in this report (**Attachment A**).

A total of five groundwater monitoring wells (M4-MW06, M4-MW07, M4-MW08, M4-MW09 and M4-MW10) comprises the quarterly groundwater monitoring program conducted by the DPW at the M-4 Landfill site. Two monitoring wells (M4-MW08 and M4-MW10) were installed in the southwestern corner of the M-4 Landfill site, one monitoring well (M4-MW07) was installed in the southeast corner, one monitoring well (M4-MW06) was installed in the northwestern corner, and one monitoring well (M4-MW10) was installed in the northern area of the M-4 Landfill site. Wells M4-MW07, M4-MW08 and M4-MW09 were installed by J.C. Anderson in December 1994, well M4-MW10 was installed by Lutz Environmental, Inc. in November 1999, and M4-MW06 was installed by Tabasco Drilling Corporation in July 2010. The wells were constructed with 4-inch diameter 10 Slot Poly Vinyl Chloride pipe ranging to depths of 15.5 to 22 feet below ground surface (bgs). Well boring logs and monitoring well records are provided in Attachment B. The locations of the five monitoring wells at the M-4 Landfill site are presented in Figure 2-3.

This section summarizes previous site work performed at the M-4 Landfill site.

2.2.1. Near Surface Soil Evaluation

To demonstrate that the existing soil cover over the M-4 Landfill site is in compliance with the Solid Waste Disposal Act of 1965, DPW characterized the near-surface soils by installing 63 borings (B01-B63) at strategic locations throughout the site. DPW performed soil borings and obtained soil samples in March 1998. Samples were collected using a 2-inch Geoprobe® Macrocore sampler. Sampling activities were performed in accordance with the *Fort Monmouth Standard Sampling Operating Procedure* (DPW 1997). A total of 126 soil samples were collected from the 63 borings and were analyzed for the presence of volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides, polychlorinated biphenyls (PCB) and total analyte list (TAL) metals. The soil boring locations in and around the M-4 Landfill site are identified in the Weston SIR (Weston 1995). The locations of the borings were established in a grid-like pattern within the previously designated boundaries of the M-4 Landfill site. The Remedial Investigation Report for Near Surface Soils (Versar 2004) provides a detailed explanation of activities performed for the M-4 Landfill site (Attachment C).

Laboratory analytical results for near-surface soil samples collected at the M-4 Landfill site is discussed below. The results were compared with the Cleanup Standards for Contaminated Sites (N.J.A.C. 7:26D), which was revised with Soil Cleanup Criteria dated May 12, 1999. Locations with exceedences of the Residential Direct-Contact Soil Cleanup Criteria (RDCSCC) were subjected to further evaluation involving compliance averaging and site-specific considerations.

2.2.2. Soil Analytical Results

Soil samples from the 63 borings at the M-4 Landfill Site were analyzed for VOCs, SVOCs, pesticides and PCBs, and metals. No VOCs were detected above their respective RDCSCC at the site. Soil cleanup criteria for SVOCs were exceeded in 11 of the 63 soil boring locations with seven SVOCs detected in site soils at concentrations above the RDCSCC. Soil cleanup criteria for pesticides were exceeded in one of the 63 soil boring locations with two pesticides detected in site soils at concentrations above the RDCSCC. Soil cleanup criteria for TAL metals were exceeded in 9 of the 63 soil boring locations with five metals detected in site soils at concentrations above the RDCSCC. The analytical results from the 126 soil samples collected from 63 borings at the M-4 Landfill are provided in Attachment C.

For many of the locations with analytical results that exceeded the RDCSCC, the "compliance averaging" approach was used to determine compliance with NJDEP technical requirements. Compliance averaging uses the average contaminant concentration in an area of concern rather than the contaminant concentration of individual samples for comparison to applicable soil cleanup criteria. The NJDEP policy for compliance averaging is presented in an article entitled, "Compliance Averaging," from the NJDEP Spring 1995 (Volume 7, No. 2 – Article 08) issue of *Site Remediation News* (NJDEP 1995).

In all cases, further analysis of the analytical results did not define a source area or level of contamination that necessitated the identification and evaluation of potential remedial actions. In most cases, either the calculated compliance average was below the respective RDCSCC or the exceedence was considered marginal. However, to address the exceedences of analytes that did not meet cleanup criteria in near-surface soils at the M-4 Landfill site, DPW incorporated a document equivalent to a Declaration of Environmental Restriction (DER) into the Fort Monmouth Master Plan for soils at the site. The DER was developed for the entire M-4 Landfill site or be restricted to specific areas of the site and specific analytes, as identified in this RIRA.

Given the inactive and undisturbed status of the landfill; the continued performance of long-term surface water and groundwater monitoring conducted at and around the M-4 Landfill site; the minimal potential for environmental and/or human health impacts; the lack of groundwater uses at or downgradient of the site; and the distribution, occurrence and relatively low concentrations of contaminants of concern (COC), a No Further Action (NFA) determination was requested for the near-surface soils at the M-4 Landfill Site and is being addressed in a separate report.

2.2.3. Landfill Cover Project

2.2.4. CEA

2.2.5. BEE

2.2.6. Sediment Quality Evaluation

Studies conducted at similar Main Post landfill sites (M-2 and M-8) indicated PCB-containing materials (e.g., electrical ballasts) disposed in each landfill. In addition, PCBs were detected in soil and/or groundwater at both the M-2 and M-8 Landfill sites. Therefore, assuming that the landfills on the Main Post had received similar waste materials, DPW initiated a sediment sampling investigation in the second quarter of 2000 to evaluate potential impacts to stream sediments in creeks and/or brooks running adjacent to the Main Post and Charles Wood (CW-3A only) landfill sites. The M-4 Landfill site was included in the sediment sampling program to supplement Weston's findings related to soil and groundwater.

To determine potential PCB-related impacts to sediments in Mill Creek, DPW collected 13 sediment samples from the surface and near-surface sediments of Mill Creek on April 13, 2000. The samples were obtained along the 360-foot portion of Mill Creek that flows adjacent to the western perimeter of the M-4 Landfill site. Sample depths ranged from surface (0-6 inches) to near-surface (6-12 inches bgs) at each boring location (Boring B-1 through B-13), with the exception of Boring B-5, which was also sampled at a depth of 18-24 inches bgs. All 13 sediment samples were analyzed for PCBs and compared to sediment sampling guidance concentrations defined in the NJDEP *Guidance for Sediment Quality Evaluations* (NJDEP 1998).

Only one of the 13 samples (B-5, collected from 6-12 inches bgs) contained a total PCB concentration (0.051 milligrams per kilogram [mg/kg]) above the laboratory Method Detection Limit (MDL). This sample result also exceeded the NJDEP Effects Range – Low (ER-L) guidance concentration of 0.023 parts per million (ppm) for total PCBs, but did not exceed the ER-M (0.180 mg/kg) or the LEL for Arochlor 1254 (0.060 mg/kg). Arochlor 1254 is the only Arochlor previously detected at the site. The SSEL for Arochlor 1254 (0.34 mg/kg) was not exceeded. The NJDEP ER-L guidance concentration for total PCB represents the concentration at which adverse benthic effects are found in approximately 10 percent of studies. No other guidance criteria were exceeded. Analysis of the remaining 12 samples, including upgradient samples, did not indicate PCBs above laboratory MDLs. Because the result at Boring B-5 exceeds only the ER-L guidance concentration, and the results of samples collected upgradient of Boring B-5 were non-detect (ND) for total PCBs, no long-term adverse benthic effects are expected in Mill Creek.

Because PCB concentrations exceeded NJDEP the ER-L guidance concentration at Boring B-5, another sample was collected from 18-24 inches bgs at this location. The deeper sample did not contain PCBs at concentrations above the MDL. Because the upgradient samples collected from locations near Boring B-5 contain PCBs above the laboratory MDL, the shallow sample result at B-5 is likely isolated. Therefore, PCBs are not expected to have significant long-term adverse benthic effects in Mill Creek. The sediment quality evaluation is addressed in the Remedial

Investigation Report and Sediment Quality Evaluation For the M-4 Landfill Site, Versar, February 2004. The report is presented in Attachment D.

2.2.7. Stream Stabilization Project

DPW contracted Princeton Hydro, LLC (Princeton Hydro), to provide streambank stabilization and erosion control design services for five areas located on the Fort Monmouth property, including the M-4 Landfill site. In a report for NJDEP dated December 5, 2008, Princeton presented the design for the proposed streambank stabilization and erosion control as well as the necessary historic background information and documentation to describe the existing conditions of the site. The report is presented in Attachment E.

The objective of the report was to describe the type of streambank stabilization and erosion control measures proposed for the project and how the proposed designs addresses issues with erosion, water quality, and stability on the subject site. The stabilization of the streambank and landfill areas is the first phase to be performed in preparation of complete landfill capping, which will be reported in a separate document and is not part of this RIRA.

For the M4 Landfill area, streambank stabilization is being proposed on both the left and right banks of Wampum Brook along the M-4 Landfill (Figure 2-4. The full engineering design is presented in the Princeton Hydro report included as Attachment E. The proposed stabilization is not anticipated to have any negative hydraulic impacts on the areas upstream or downstream of the M-4 Landfill site. The proposed stabilization will prevent additional scour and erosion of the streambanks on the site and thereby reduce the stream's pollutant load, and increase sediment removal functions associated with the establishment of integrated vegetative cover (Princeton Hydro 2008).

2.2.8. Offsite Receptor Evaluation

An Offsite Receptor Report, dated October 13, 2010, was prepared by Tetra Tech surrounding a central point of the Main Post and Charles Wood areas. A copy of the offsite receptor evaluation report is provided in Attachment F.

Fort Monmouth DPW and their subcontractor performed a visual and documentary search to identify any potentially sensitive populations within 200 feet of the Fort Monmouth boundary. The search was performed in accordance with NJDEP statutory requirement.

Although sensitive populations were identified within 200 feet of the Fort Monmouth boundary, all of the environmentally impacted locations are a significant distance from the fence line and in all cases exceed the 200-foot buffer established by NJDEP.

In addition to the sensitive receptors, DPW identified off-site wells within 2,000 feet of the Fort Monmouth perimeter. No production wells were identified within 2,000 feet of the Fort Monmouth boundary. The majority of off-site wells are monitoring wells associated with various remedial activities. In their groundwater model developed for Fort Monmouth, Brinkerhoff Environmental Services, Inc. (Brinkerhoff), determined that the overall groundwater

flow pattern for the Main Post is easterly with a localized northeasterly component. Fort Monmouth is bounded by surface water bodies to the east and northeast. Any domestic and/or irrigation wells to the east or northeast of the Main Post would not be impacted by the base (Brinkerhoff 2010).

Surface water bodies interact with groundwater at Fort Monmouth. The interaction takes place in three basic ways: (1) streams gain water from inflow of groundwater through the streambed, (2) streams lose water to groundwater by outflow through the streambed, or streams do both--gaining in some reaches and losing in other reaches. When groundwater discharges into a surface water body, the altitude of the groundwater table in the vicinity of the creek must be higher than the altitude of the stream water surface. Conversely, for surface water to seep to groundwater, the altitude of the water table in the vicinity of the stream must be lower than the altitude of the stream water surface. The surface water bodies at Fort Monmouth (Oceanport and Parkers Creeks) may be gaining or losing depending upon the tidal cycle. Throughout the entire tidal cycle, however, the net result is that groundwater flows into the creeks, albeit at low flow rates.

2.3. CURRENT CONDITIONS

On October 21, 2010, Tetra Tech conducted a drive by to assess current conditions at the M-4 Landfill site. The site consisted of an open field, which is maintained through landscaping.

2.4. ENVIRONMENTAL SETTING

This section summarizes the description of the geological and hydrogeological setting of the area surrounding Fort Monmouth and the Main Post area as presented in Versar, Inc.'s (Versar), 2005 Remedial Investigation Report (RIR) (Attachment G) (Versar 2005).

2.4.1. Geology

Monmouth County lies within the New Jersey Section of the Atlantic Coastal Plain physiographic province. The M-4 Landfill site is located in what may be referred to as the Outer Coastal Plain subprovince, or the Outer Lowlands.

In general, New Jersey Coastal Plain formations consist of a seaward-dipping wedge of unconsolidated deposits of clay, silt, sand, and gravel. These formations typically strike northeast-southwest with a dip ranging from 10 to 60 feet per mile and were deposited on Precambrian and lower Paleozoic rocks. These sediments, predominantly derived from deltaic, shallow marine, and continental shelf environments, date from Cretaceous through the Quaternary periods. The mineralogy ranges from quartz to glauconite.

As presented in the Site Investigation Report - Main Post and Charles Wood Areas, Fort Monmouth, New Jersey, prepared by Weston (Weston 1995), several natural and anthropogenic factors contribute to the wide range in concentrations of metals found in soils, which further impact the concentration of metals in groundwater. Soils derived from the glauconitic sands contain abundant aluminum, calcium, potassium, iron, magnesium, and manganese (among

others), which are likely to be present at elevated concentrations in the groundwater, particularly when sediments are entrained in the collected groundwater samples.

2.4.2. Hydrogeology

A description of the hydrology of the site is provided in Section 2.4.2 of **Attachment G** (Versar 2005).

Brinkerhoff prepared the *MODFLOW Groundwater Modeling Report*, dated June 10, 2010, which is included as Attachment H. In this report, Brinkerhoff developed and refined site-wide groundwater models for both the Main Post and the Charles Wood areas of Fort Monmouth (Brinkerhoff 2010).

As part of the groundwater modeling project, Brinkerhoff performed a Preliminary Tidal Evaluation of select monitoring wells throughout the Main Post of Fort Monmouth. The study locations were mutually selected by Brinkerhoff and representatives of Fort Monmouth. These locations were chosen to represent an overall profile for the Main Post area. On September 29, 2009, wireless downhole data loggers were placed into each of the 25 predetermined groundwater monitoring wells targeted for the study. Data was collected for approximately 30 days.

Monitoring wells M4MW05, MW4MW07, and M4MW10 were included in this evaluation of the M-4 Landfill area. The area of the M-4 Landfill is along the east side of Mill Creek to the south of the confluence of Mill Creek and Parkers Creek. M4MW10, which is directly adjacent to Mill Creek, exhibited a rhythmic cycle of groundwater fluctuations indicative of tidal influence. Additionally, groundwater data collected for M4MW07, approximately 160 feet east of Mill Creek, did not appear to indicate tidal influence; however, subtle fluctuations corresponding with large rainfall events were apparent. Although it is not tidally influenced, the location of M4MW7 indicates that it is susceptible to irregular groundwater elevation changes caused by surface water permeation. Areas with groundwater elevations less than 5 feet above mean sea level (amsl) are considered within the Primary Zone of potential tidal influence. Groundwater elevations for the M-4 Landfill site ranged from 2.5 to 7.1 feet amsl; therefore, the M-4 Landfill site is not considered to be within the Primary Zone of potential tidal influence (Brinkerhoff 2010).

According to the modeling report, the suggested flow directions indicated by the groundwater flow model are generally consistent with that seen in previous groundwater investigations when compared to groundwater contour maps prepared using depth-to-water measurements collected in the field on January 28, 2010. The groundwater contour map illustrating the January 2010 measurements at the M-4 Landfill site area created as part of the groundwater modeling report is presented as Figure 2-5 The groundwater contour map suggests that groundwater at the site flows toward the west (Brinkerhoff 2010).

In general, groundwater flows from areas of relatively high topographic elevations toward lower topographic elevations where site surface water features are present. The MODFLOW simulation shows that the central portion of the Main Post is a relatively high groundwater divide

because this portion of Fort Monmouth is almost completely surrounded by low-elevation surface water. The Main Post area can be characterized as having a small hydraulic gradient. When combined with the low hydraulic conductivity of the aquifer materials, this translates into very slow groundwater migration. Particle markers, which represent typical travel paths and speeds for water molecules in the system, indicate extremely long travel times. In several areas of the Main Post, representative markers did not reach the nearest surface water sink within the 200-year travel time shown. As a result of the slow groundwater velocity, recharge to the aquifer from rainfall, although very limited, has the effect of adding a downward component to the groundwater flow (Brinkerhoff 2010).

The physical conditions of the site would likely contribute to groundwater contaminant plumes with a dominant elongation in a downgradient direction. Vertical contaminant migration would typically be heavily impeded by the fine-grained aquifer materials present at depth (Brinkerhoff 2010).

3.0 SITE ACTIVITIES

To define the areal extent of potential pollutants and evaluate impacts to groundwater in the vicinity of the M-4 Landfill site, Fort Monmouth DPW conducted remedial investigation activities at the M-4 Landfill site including quarterly groundwater and surface water sampling. Remedial groundwater investigation activities were conducted between April 2001 and July 2010. Remedial surface water investigation activities were performed from May 2001 through September 2010. Remedial investigation activities were managed by the Fort Monmouth DPW and performed by TECOM-Vinnell Services (TVS) and reported herein by Tetra Tech.

The details of remedial investigation activities that occurred at the M-4 Landfill—including groundwater depth measurements, groundwater sampling activities, and surface water sampling activities—are described in the following sections.

3.1. GROUNDWATER DEPTH MEASUREMENTS

During each round of the groundwater sampling, measurements of the depth to water in each of the monitoring wells were recorded with an accuracy of 0.01 foot. These depth-to-groundwater measurements, recorded from April 2001 through July 2010, are presented in Table 3-1. The groundwater elevation at each well was calculated by subtracting the elevation of the top of the well casing with the depth to water at the well.

3.2. GROUNDWATER SAMPLING ACTIVITIES

As a part of the remedial investigation, quarterly groundwater sampling was conducted by the DPW between April 2001 and July 2010 at the M-4 Landfill site. Sampling activities were performed in accordance with the Fort Monmouth Standard Sampling Operating Procedure (DPW 1997).

Groundwater samples were collected during 38 quarterly sampling events. On November 16, 2004, NJDEP approved DPW's request to reduce the groundwater sampling analytical parameters at the M-4 Landfill site. Starting the first quarter of 2005, groundwater sampling analysis for site was reduced to TAL metals only. Between April 2001 and October 2004, the groundwater samples were analyzed for VOCs, SVOCs, pesticides, PCBs and TAL metals. Between January 2004 and July 2010, groundwater samples were analyzed for TAL metals only. Two additional low-flow sampling rounds were conducted and samples were analyzed for TAL metals. A total of 190 samples were collected throughout the groundwater sampling program.

Copies of the chain-of-custody forms for the laboratory analyses, sample IDs, collection/analysis dates, analytical parameters, and analytical methods can be found in Attachment I. The results of these analyses are discussed in Section 5.0.

Because of the potential benefits of low-flow sampling, two rounds of low-flow sampling (Low-flow #3 and Low-flow #4) were conducted on April 6, 2010 and July 21, 2010, respectively. Of the 190 total groundwater samples, 20 samples were collected and analyzed for TAL metals to determine whether elevated metal concentrations observed in the groundwater samples were

caused by sediments rather than groundwater. The samples were analyzed by the Fort Monmouth Environmental Testing Laboratory (FMETL) for TAL metals utilizing U.S. Environmental Protection Agency (EPA) Methods 3120B and 3112B. These analytical results are discussed in Section 5.1.

Sampling equipment was thoroughly decontaminated before and after each use, in accordance with Fort Monmouth Standard Operating Procedures (DPW 1997). The groundwater samples were collected and immediately placed in laboratory-supplied bottleware. The sample containers were labeled, sealed, packed in ice, and transported to FMETL in accordance with proper chain-of-custody procedures.

3.3. SURFACE WATER SAMPLING ACTIVITIES

To determine whether groundwater contamination at the M-4 Landfill site has impacted nearby surface water, DPW conducted quarterly surface water sampling at the M-4 Landfill site between May 2001 and September 2010. Of the three surface water (stream) sampling locations associated with the site (SS-5, SS-15, and SS-16), SS-5 and SS-15 were sampled between May 2001 and September 2010; SS-16 was sampled between May 2001 and August 2004 only. A total of 90 surface water samples was collected during 38 quarterly sampling events and analyzed for VOCs. Beginning the fourth quarter of 2004 through September 2010, SS-15 was also analyzed for TAL Metals. A total of 38 surface water samples was collected from SS-5 and SS-15; 14 surface water samples were collected from location SS-16. Figure 3-1 depicts the locations of the three surface water stream sampling locations at the M-4 Landfill site.

Sampling equipment was thoroughly decontaminated before and after each use in accordance with the Fort Monmouth Standard Operating Procedures (DPW 1997). The surface water samples were collected and immediately placed in laboratory-supplied bottleware. The sample containers were labeled, sealed, packed in ice and transported to the FMETL under proper chain-of-custody procedures. Copies of the chain-of-custody for the laboratory analyses, sample IDs, stream sampling locations, collection/analysis date, analytical parameters and analysis method can be found in Attachment I. The results of the surface water sampling program are discussed in Section 5.0.

4.0 SITE PHYSICAL CHARACTERISTICS

The following sections represent the findings of the site geologic and hydrogeologic characterization program for the M-4 Landfill site. DPW collected the groundwater elevation data between April 2001 and September 2010. Specifically, this section summarizes lithology and groundwater flow direction data collected for the area surrounding the M-4 Landfill site.

4.1. LITHOLOGY

The lithology encountered at the M-4 Landfill site consists primarily of fill material (sand, silt, broken concrete, gravel, and plant fragments), fine sand, and clay. Geologic cross-section A-A' was prepared for two monitoring wells. Cross-section A-A' depicts the profiles for monitoring wells M4-MW07 and M4-MW10. Wells M4-MW07 and M4-MW10 encountered fill consisting of crushed concrete, sand with silty clay laminae, organics (grass roots), greenish gray to black silty clay, and coarse sand with iron oxide laminae ranging from 0.5 to 18 feet bgs.

As discussed in the 1995 SIR, the wide range of concentrations of metals in soils further impact the concentration of metals detected in groundwater (Weston 1995). Soils derived from glauconitic sands contain abundant aluminum, calcium, potassium, iron, magnesium, and manganese (among others), which are likely to be present at elevated concentrations in the groundwater, particularly when sediments are entrant during the collection of groundwater samples.

4.2. GROUND WATER FLOW DIRECTION

Groundwater contour maps were generated based on groundwater depth measurements from the five monitoring wells collected between April 2001 and July 2010. Groundwater was encountered at the M-4 Landfill site at depths ranging from 2.5 feet to 7.1 feet bgs, grading toward Mill Creek. The groundwater underlying the site appears to be flowing consistently west towards Mill Creek.

5.0 SITE CHEMICAL CHARACTERIZATION

This section includes a discussion of the chemical characterization of the M-4 Landfill site based on various samples collected and analyzed from the site, including 36 rounds of groundwater monitoring well samples, two rounds of low-flow groundwater samples, and 38 rounds of surface water samples. DPW personnel were responsible for the collection of samples during this remedial investigation. Sample analyses were performed by FMETL, a New Jersey certified laboratory (Certification No. 13461).

Groundwater analytical data was compared against NJDEP criteria and COCs were identified based on those results. Groundwater data was compared to NJDEP Groundwater Quality Standards (GWQS) or Practical Quantitation Limits (PQL), whichever was higher.

According to the 2008 SIR Report prepared by Shaw Environmental (Shaw), several factors, both natural and anthropogenic, can influence chemical concentrations, specifically metals, found in environmental samples collected at Fort Monmouth. The primary natural influence at Fort Monmouth is parent material: glauconitic quartzose sands of the Tinton and Red Bank sands and their fluvially- and tidally-reworked equivalents. The mineral glauconite found in these sands is a potassium-, sodium-, calcium-, iron-, aluminum-, magnesium-rich hydrosilicate. These glauconitic soils therefore contain abundant iron, aluminum, calcium, magnesium, manganese, sodium, and potassium (Shaw 2008).

Groundwater quality is often affected by the composition of the aquifer; in this case, the Tinton and Red Bank sands. Coastal Plain aquifers are susceptible to saltwater encroachment. Aquifers under Fort Monmouth can also be identified by saltwater intrusion, affecting groundwater chemistry. High concentrations of sodium are likely a result of saltwater intrusion (Shaw 2008).

As a result of these natural influences, aluminum, calcium, iron, manganese, magnesium, potassium, and sodium are likely to be present in elevated concentrations and are not considered COCs in soil and groundwater at Fort Monmouth. Therefore, these metals were not included in groundwater results presented in Table 5-1. All other analytical results for environmental samples collected at Fort Monmouth as part of the remedial investigation were compared with applicable NJDEP criteria and the MBCs, if applicable. If they exceeded the NJDEP regulations, sample concentrations were compared to the MBC. Those compounds that exceeded the regulatory standard and established background levels were classified as COCs. Laboratory data for all analytes, including the metals listed above, are provided in Attachment I.

This section summarizes groundwater sampling results, surface water sampling results, COCs, and quality assurance and quality control (QA/QC) sampling results for the M-4 Landfill site.

5.1. GROUNDWATER SAMPLING RESULTS

This section presents the results of laboratory analyses performed for the 36 rounds of groundwater sampling and 2 additional low-flow sampling conducted from 2001 through July 2010 from the five monitoring wells (M4-MW06, M4-MW07, M4-MW08, M4-MW09, and M4-MW10) at the M-4 Landfill site. Between April 2001 and October 2004 (rounds 1 through 15)

groundwater samples were collected and analyzed for VOCs plus 15 tentatively identified compounds (TIC), SVOCs plus 15 TICs, pesticides, PCBs, and TAL metals.

On November 16, 2004, NJDEP approved DPW's request to reduce the analyses performed on groundwater samples collected at the M4 Landfill site. Starting the first quarter of 2005, groundwater sampling analysis for M4 Landfill was reduced to only TAL metals. Between January 2004 and July 2010 (rounds 16 through 38), groundwater samples were analyzed for TAL metals only.

As discussed in Section 2.2.1, low-flow sampling methodology was proposed by the DPW to assess the impact of suspended sediments on the dissolved-phase metals concentrations at the site. Two rounds of low-flow sampling (Low-flow #3 and Low-flow #4) were conducted on April 6, 2010 and July 21, 2010 (respectively), using a low-flow groundwater sampling technique for TAL metals.

Fort Monmouth is underlain by a Class III-A aquifer. The groundwater quality criteria for Class III-A is considered to be the criteria for the most stringent classification for vertically or horizontally adjacent groundwaters that are not Class III-A (N.J.A.C. 7:9-6.7E). The NJDEP criteria used for comparison of groundwater analytical results were the higher of the PQLs and the NJDEP GWQC for Class II-A aquifers (N.J.A.C. 7:9-6, Table 1) (NJDEP 1999b).

During the 15 quarterly sampling events conducted prior to the NJDEP approval letter for the reduction of groundwater sampling analyses, no VOCs or PCBs were detected in site groundwater. Six SVOCs were detected in site groundwater at concentrations below their respective NJDEP GWQC. Three pesticides were detected in site groundwater at concentrations below their respective NJDEP GWQC. A total of 11 metals was detected in site groundwater with two metals detected at concentrations above their respective NJDEP GWQC.

Following the reduction of sampling analyses approval from the NJDEP, 12 metals were detected in site groundwater during the last 18 sampling quarters, with seven metals detected at concentrations above their respective NJDEP GWQC.

This section discusses analytical results of groundwater samples collected from the M-4 Landfill site according to the four analytical categories: VOCs, SVOCs, pesticides and PCBs, and TAL metals. These four sections will concentrate on the most recent eight quarters of sampling conducted between October 2008 and July 2010. These eight quarters define the most current conditions of groundwater at M4-Landfill.

5.1.1. Volatile Organic Compounds

No VOCs were detected above their respective NJDEP GWQC at the site.

5.1.2. Semi Volatile Organic Compounds

No SVOCs were detected above their respective NJDEP GWQC at the site.

5.1.3. Pesticides and PCBs

No pesticides or PCBs were detected above their respective NJDEP GWQC at the site.

5.1.4 TAL Metals

During the most recent eight sampling events, including two rounds of low-flow sampling, seven TAL metals were detected at concentrations exceeding the NJDEP GWQC in at least one sample at the M-4 Landfill site.

Antimony was detected at concentrations exceeding the GWQC of 6 micrograms per liter (µg/L) during 5 separate rounds of sampling conducted at four separate monitoring well locations. Concentrations ranged from 6.51 µg/L in M4-MW08 to 18.7 µg/L in M4-MW8.

Arsenic was detected at concentrations exceeding the GWQC of 3 µg/L during 5 separate rounds of sampling conducted at four separate monitoring well locations. Concentrations ranged from 3.61 µg/L in M4-MW09 to 109 µg/L in M4-MW08.

Beryllium was detected at concentrations exceeding the GWQC of 1 µg/L during one round of sampling conducted at one monitoring well location (M4-MW07) at a concentration of 1.28 µg/L.

Cadmium was detected at concentrations exceeding the GWQC of 4 µg/L during one round of sampling conducted at one monitoring location (M4-MW08) at a concentration of 9.23 µg/L.

Lead was detected at concentrations exceeding the GWQC of 5 µg/L during three separate round of sampling conducted at three separate monitoring well location. Concentrations ranged from 5.0 µg/L in M4-MW09 to 31.1 µg/L in M4-MW08.

Selenium was detected at concentrations exceeding the GWQC of 40 µg/L during one round of sampling conducted at three separate monitoring well location at a concentration ranging from of 52.7 µg/L to 87.0 µg/L.

Thallium was detected at a concentration exceeding the GWQC of 2 µg/L during one round of sampling conducted at one monitoring well location (M4-MW09) with a concentrations of 2.02 µg/L.

5.2. SURFACE WATER SAMPLING RESULTS

To determine whether groundwater contamination at the M-4 Landfill site has impacted nearby surface water, DPW conducted quarterly surface water sampling at the M-4 Landfill site between May 2001 and September 2010. Of the three surface water (stream) sampling locations, SS-5 and SS-15 were sampled between May 2001 and September 2010; SS-16 was sampled between May 2001 and August 2004 only. A total of 90 surface water samples was collected during 38 quarterly sampling events and analyzed for VOCs. However, beginning the fourth quarter of 2004 through September 2010, SS-15 was also analyzed for TAL metals. A total of 38 surface

water samples was collected from each of the two stream locations (SS-5 and SS-15). Fourteen surface water samples were collected from the stream location SS-16. Figure 3-1 depicts the locations of the surface water stream sampling locations associated with Fort Monmouth and the M-4 Landfill site. The samples were collected by the DPW and analyzed by the FMETL for VOCs and TAL metals.

This section discusses analytical results of surface water samples collected from the M-4 Landfill site according to the two analytical categories: VOCs and TAL metals. These four sections will concentrate on the most recent eight quarters of sampling conducted between December 2008 and September 2010, which define the most current conditions of surface water at M-4 Landfill site. SS-16 is not included in this discussion because sampling at that location was discontinued in August 2004 and would not represent the most current condition of surface water at M4-Landfill. SS-16 is located between SS-15 and SS-05 and is downstream of SS-15. Because of its location, the results from SS-15 and SS-05 are representative of that particular stretch of the stream. All the laboratory analytical results for surface water samples (including results for SS-16) are summarized in Table 5-2.

5.2.1. Volatile Organic Compounds

Five VOCs were detected in site surface water: two VOCs were detected above the health-based NJDEP fresh water criteria and the remaining three VOCs were detected below the health-based NJDEP fresh water criteria.

Tetrachloroethene (PCE) was detected at concentrations exceeding the NJDEP criteria of 0.34 µg/L during the last eight quarterly rounds of sampling conducted at two separate surface water stream sampling locations. Concentrations ranged from 0.42 µg/L at SS-5 to 3.03 µg/L at SS-15.

Trichloroethene (TCE) was detected at a concentration exceeding the NJDEP criteria of 1.00 µg/L during one of the last eight rounds of quarterly sampling conducted at one surface water stream sampling location at a concentration of 1.26 µg/L at SS-15.

5.2.2. TAL Metals

Eleven metals were detected in site surface water with, four metals detected above the health-based NJDEP fresh water criteria and the remaining seven metals detected below the health-based NJDEP fresh water criteria.

Antimony was detected at concentrations exceeding the NJDEP criteria of 5.6 µg/L during five of the last eight rounds of quarterly sampling conducted at one surface water stream location. Concentrations ranged from 6.06 µg/L to 17.8 µg/L.

Arsenic was detected at concentrations exceeding the NJDEP criteria of 0.017 µg/L during five of the last eight rounds of quarterly sampling conducted at one surface water stream location. Concentrations ranged from 1.13 µg/L to 66.6 µg/L.

Lead was detected at a concentration exceeding the NJDEP criteria of 5.00 µg/L during one round in the last eight rounds of quarterly sampling conducted at one surface water stream location at a concentration of 5.74 µg/L

Mercury was detected at a concentraion exceeding the NJDEP criteria of 0.05 µg/L during one round in the last eight rounds of quarterly sampling conducted at one surface water stream location at a concentration of 0.18 µg/L.

5.3. CONTAMINANTS OF CONCERN

No VOCs, SVOCs, pesticides, or PCBs were detected in the groundwater samples collected from the M-4 Landfill site at concentrations exceeding the NJDEP GWQC criteria. A total of seven metals (antimony, arsenic, beryllium, cadmium, lead, selenium, and thallium) were detected in groundwater samples at concentrations exceeding the NJDEP GWQC. Figure 5-3 shows the specific exceedances from the last 8 sampling quarters. The specific exceedences and each constituent considered to be a potential COC are discussed below and are presented in Table 5-3 for groundwater and Table 5-4 for surface water.

A low-flow sampling methodology was used to reduce the presence of suspended sediments within the groundwater samples collected from the M-4 Landfill site. Significant decreases in non-native metals (arsenic, antimony, beryllium, cadmium, lead, selenium, and thallium) and in naturally occurring metals (aluminum, barium, calcium, copper, iron, magnesium, manganese, nickel, potassium, sodium, and zinc) were seen in the sample results after the low-flow sampling events. However, the native metal constituents (those indigenous to the soils at Fort Monmouth) were consistently present in the groundwater samples collected from the M-4 Landfill site.

The two separate rounds of low-flow groundwater sampling conducted in April and July 2010, respectively, were performed during the quarterly groundwater sampling program at the M-4 Landfill site. This technique was used to determine whether the detected metal concentrations observed in the groundwater samples were caused by contaminated sediments suspended in the groundwater during the course of well purging and sampling activities, or whether sampling results were an accurate representation of aquifer/groundwater conditions. This low-flow sampling approach resulted in the reduction of concentrations or the non-detections of six uncharacteristic metals (arsenic, beryllium, cadmium, lead, selenium, and thallium) during the two rounds of low-flow groundwater sampling conducted at the M-4 Landfill site. Concentrations of antimony detected during the low-flow sampling events continued to exceed the GWQC criteria.

The groundwater analytical results were compared with the low-flow sampling results and the NJDEP GWQC. As a result of this comparison, six metals were eliminated as COCs in groundwater at the M-4 Landfill site. Antimony concentrations exceeded the NJDEP criteria even after comparison to the low-flow sampling results. However, because concentrations of antimony were below the MBC for Fort Monmouth, antimony is not considered a COC in groundwater at the M-4 Landfill site.

Two VOCs (PCE and TCE) and four metals (antimony, arsenic, lead, and mercury) were detected at concentrations exceeding the NJDEP SWQS. PCE was detected in surface water above the NJDEP criteria from two stream sampling locations (SS-5 and SS-15) sampled during five of the last eight rounds of sampling. TCE was detected in surface water collected from one stream sampling location (SS-15) above the NJDEP criteria only once in the last eight sampling events. However, because these compounds were not detected in groundwater and are not considered to impact nearby surface water at the M-4 Landfill, PCE and TCE are not considered to be COCs. Mercury was detected in one surface water sampling location above the NJDEP criteria only once in the last eight quarters. Because of the infrequency and magnitude of exceedances in surface water, mercury is not considered a COC. Lead, antimony, and arsenic were detected in one surface water sampling location (SS-15) above the NJDEP criteria. However, lead, antimony, and arsenic were eliminated as COCs in groundwater at the site and therefore are not considered to impact nearby surface water at the M-4 Landfill site.

The highest concentrations of the VOCs and metals were detected in surface water samples collected from SS-15, which is located at the boundary of Fort Monmouth and is upgradient of the M-4 Landfill site. It is the DPW's contention that the concentrations of the two VOCs and four metals detected above the NJDEP SWQS in the surface water samples are from a source beyond the boundary of Fort Monmouth. Therefore, no VOCs and metals are identified as COCs in surface water at the M-4 Landfill site.

5.4. QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance and quality control (QA/QC) samples were collected in accordance with the current version of the NJDEP Field Sampling Procedures Manual in effect at the time sampling was conducted. A total of 23 duplicates, 38 field blanks and 15 trip blanks were collected. No evidence of any QA/QC issues were identified based on the results of the QA/QC sample results.

6.0 CONCLUSIONS

Geologic publications indicate that the M-4 Landfill site is located within an aquitard (the Navesink-Hornerstown Confining Unit). The low hydraulic conductivity of the aquitard and the thickness of the aquitard at the site conform to the requirements of a Class III-A aquifer, as specified in the NJDEP Groundwater Quality Standards (N.J.A.C. 7:9-6, January 7, 1993).

The analytical results for the groundwater samples collected at the M-4 Landfill site between April 2001 and July 2010 indicate that no COCs exist within the M-4 Landfill site groundwater. The Class II-A criteria were used for comparison with site-specific data obtained from the various groundwater sampling rounds because the Ground Water Quality Standards (N.J.A.C. 7:9-6.7E) state that the groundwater quality criteria to be used for Class III-A aquifers are the most stringent criteria associated with vertically or horizontally adjacent groundwaters that are not Class III-A (NJDEP 1999b).

Based on the results of the groundwater quality evaluation, no VOCs, SVOCs, pesticides or PCBs were detected in groundwater samples collected at the M-4 Landfill site in concentrations in excess of the NJDEP GWQC. The seven non-native metals that exceeded the NJDEP cleanup criteria were eliminated as COCs in groundwater at the M-4 Landfill site as a result of a comparison between the groundwater sampling results, the low-flow sampling results, and the MBCs. The two VOCs and four metals detected in surface water above the NJDEP SWQS were eliminated as potential COCs in surface water because they are not considered potential COCs in groundwater and are therefore not impacting nearby surface water at the M-4 Landfill site. It is the DPW's contention that the concentrations of the two VOCs and four metals detected above the NJDEP SWQS in the surface water samples are from a source beyond the boundary of Fort Monmouth. Therefore, no VOCs or metals are identified as COCs in surface water at the M-4 Landfill site.

Based on analytical results for M-4 Landfill site, further remedial investigation activities at the site are not required. Tetra Tech recommends continued groundwater and surface water monitoring, in agreement with the fiscal year 2010 Fort Monmouth Base Realignment and Closure (BRAC) Installation Action Plan (BIAP). No Further Action (NFA) is recommended with respect to surface water and groundwater at the site.

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TABLES

FIGURES

ATTACHMENTS